KING AND TANNER CRAB RESEARCH IN ALASKA:

SEMIANNUAL REPORT FOR

JULY 1, 1994 THROUGH DECEMBER 31, 1994

Submitted Under Cooperative Agreement NA37FL0333 To

National Oceanic and Atmospheric Administration
National Marine Fisheries Service
P.O. Box 21668
Juneau, Alaska 99801

Submitted By

Gordon H. Kruse
ADF&G Project Coordinator

Regional Information Report No. 5J95-02
Alaska Department of Fish & Game
Commercial Fisheries Management and Development Division
P.O. Box 25526
Juneau, Alaska 99802-5526

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PURPOSE OF DOCUMENT

Under cooperative agreement NA37FL033 between the Alaska Department of Fish and Game (ADF&G) and National Marine Fisheries Service (NMFS), research is funded that is germane to the optimal management of lucrative king *(Paralithodes, Lithodes)*, Tanner *(Chionoecetes bairdi)* and snow crab *(Chionoecetes opilio)* fisheries in the waters off the state of Alaska. ADF&G was awarded $237,500 during this second year of funding, state fiscal year 1995 (FY 95), which covers July 1, 1994 through June 30, 1995. The purpose of this report is to summarize work progress by ADF&G through mid-year (July 1, 1994 through December 31, 1994).

Specifically, this report briefly summarizes: (1) the long-term research strategy; (2) overall plan for second-year research; and (3) individual projects including background, project descriptions, current year goals, mid-year progress, and plans for the remainder of the year. Project summaries were authored by project leaders as noted below. Other sections were authored by the ADF&G Project Coordinator, Gordon Kruse.

OVERALL LONG-TERM RESEARCH STRATEGY

The Gulf of Alaska (GOA), Aleutian Islands area (AI), and Bering Sea (BS) support large commercial fisheries on king, Tanner and snow crabs. Many crab stocks crashed in the 1980s, and many fisheries are closed due to low abundance. Poor success of maintaining productive fisheries over the long-term has prompted a re-evaluation of management strategies. Kruse (1994c) proposed that wise management of fisheries can only be accomplished by providing answers to four fundamental questions: (1) what are the stocks?, (2) how abundant are they?, (3) what features drive their productivity?, and (4) how should this productivity be harvested? A work group of ADF&G and NMFS crab researchers and managers developed a long-term work plan for research to answer these questions (Kruse 1994c). Progress on the plan was discussed at an annual meeting of state and federal researchers (Kruse 1994d).

OVERALL PLAN FOR SECOND YEAR

Pursuant to the statement of work for the second year of funding (Kruse 1994a), research is being conducted into four areas of investigation: (1) relative roles of fishing, predation and environment on long-term dynamics of Alaska crab stocks; (2) gear modifications to ameliorate potential effects of handling mortality on red king crabs; (3) crab genetics; and (4) population estimation and alternative harvest strategies. Projects (1) and (2) are being conducted by the University of Alaska Fairbanks (UAF) through Reimbursable Services Agreements to ADF&G. Below are summaries of these four ongoing research projects, as well as updates on two projects that were funded in FY 94 only: reproduction of Tanner crabs and nearshore crab studies.

PROJECT 1: LONG-TERM DYNAMICS OF ALASKAN CRAB STOCKS

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Background and Need

Three decades of catch histories and one to two decades of stock assessments reveal a wide range of crab population trends. To date, most stocks have crashed and not improved, some others have crashed and recovered, and still a few others remain healthy despite large fisheries. A number of causes of these dynamics have been proposed, including anthropogenic and natural causes. More specifically the main suggestions for stock demise are overfishing, handling mortality, predation, and oceanographic changes. Despite wide speculation about the relative roles of various factors on crab populations, the supporting evidence for the alternatives has never been objectively evaluated.

Project Description

The purpose of this multi-year project is to investigate relative effects of fishing (overharvest and handling mortality) and natural changes (predation and oceanography) on the long-term dynamics of crab populations in Alaskan waters. This will be accomplished through five ongoing phases of research.

First, data bases will be compiled relevant to variables that would be implicated in possible causes of change, including crab spawning stock abundance and recruitment, oceanographic variables, and predator abundance. Second, two workshops will be conducted with crab biologists and physical oceanographers to develop a conceptual model of causal mechanisms by which fishing, predation, and oceanography could act on the long-term dynamics of Alaskan crab populations. One workshop was held in spring 1994, and the second is planned for spring 1995.

Third, analyses will be conducted to characterize intrinsic features of the data sets, such as time intervals between successful crab year classes, periods of increased predator abundance, and years of favorable ocean conditions during crab larval stages. Fourth, the causal mechanisms will be stated in terms of alternative hypotheses and tested with available data sets by a range of statistical methods.

Last, based on the above results, the most likely mechanisms will be selected for inclusion in a computer simulation model to fully explore the relative roles of these competing factors on crab populations. The simulation model will be used to identify possible confounding effects of several mechanisms that may interact in sequential and non-linear ways not amenable to standard statistical methods.

Goals for FY 95

During the second year, the following milestones have been planned:

(1) Additional relevant biological and oceanographic data will be procured from ADF&G, NMFS, and National Oceanic and Atmospheric Administration (NOAA). Tanner and snow crab data will be added to the king crab data already in hand. Data will be compiled into an electronic data base suitable for analysis.

(2) A workshop will be conducted with biologists and oceanographers to identify possible mechanisms responsible for the observed Tanner crab population dynamics.

(3) Analyses will be conducted to gain insights into the nature of the historic variability in both king and Tanner crab populations, their predators, and the environment.

Mid-Year Progress

A conceptual model of the formation of red king crab year-class strength was developed using a events-time approach. By this procedure a stage by stage description was developed in tabular format of the life history events and accompanying processes pertaining to survival rates. This included the location and timing of the life stages, along with the coincident physical oceanographic and biological factors that could influence the productivity and survival rate of the stages. The result was a series of hypotheses related to year-class strength that represented the combined information of the biologists who participated in the modeling workshop. A manuscript has been written and edited for publication that describes the workshop and its findings. In addition an abstract has been submitted to the Lowell Wakefield Symposium on crabs from high latitude habitats to be held in Anchorage during October 1995.

The hypotheses were ordered within eight life history stages that presumably formed clusterings of similar survival processes: Stage 1 - development of the egg clutch; Stage 2 - mating and egg fertilization; Stage 3 - hatch timing; Stage 4 - survival during hatching; Stage 5 - survival during zoeal stages; Stage 6 - survival during the glaucothoe stage; Stage 7 - juvenile survival (ages 1-6); and Stage 8 - survival during adult stages (ages 5 to 15).

Several key hypotheses have emerged relating survival to oceanographic factors as follows: a critical number of degree-days is necessary to bring on ovary maturation; once eggs are "ripe" cool temperatures will delay spawning, and high temperatures following fertilization will increase egg mortality; initiation of hatching apparently depends on a water quality cue that is related to the abundance of a particular species of diatom; and high percentage hatch is linked to optimum temperature. For the larval stages, water-mass mixing due either to tide or Ekman transport increases nutrients used in primary production; since high-profile, rocky bottom-type is critical for survival of the glaucothoe

stage during settling, an increase in the strength of currents moving larvae away from this bottom type would increase mortality.

Other hypotheses are related to predation and biological factors that influence survival of the various stages. Main hypotheses are as follows: fecundity increases with crab size; a molt may be skipped if egg development is delayed; fecundity and molt frequency are dependent on rations; fertilization rate is higher with larger males; timing of mating depends on water temperature as well as the female's previous reproductive history, predation rate is likely to be variable on the zoeal larvae depending on the abundance of predators, particularly walleye pollock, sockeye salmon, and euphausids; the cannibalistic nature of newly settled glaucothoe larvae leads to density dependent mortality; predation rate on juveniles is variable and dependent on abundances of predators, particularly sea otters *(Enhydra lutris)*, Pacific cod *(Gadus macrocephalus)*, and sculpins; and competition with flatfish will likely bring about reduced growth rates and molting frequency.

Plans for Remainder of Year

During the next six months development of the conceptual model of the Bristol Bay king crab stock will be finished. In particular the logical structure for the model will be completed and the functional relationships will be developed and graphed. These graphs express the hypothetical effects of oceanographic and population variables on survival of life history stages. A paper on the recruitment workshop will be published in an ADF&G report series.

Because of the lack of information it is unlikely that a computerized model will result from the conceptual model. In particular there is little on which to base the scaling of many of the graphs of the possible functional relationships. The ranges of parameters of these functions are not possible to set even hypothetically. Still, the formalized model will give insight into the kinds of research programs that will lead to an effective evaluation of what is known of the mechanisms that influence year-class strength, in particular, the influence of predation, effects of physical oceanographic factors and relationships involving density dependent survival and productivity stemming from limited food supply. All known and relevant information about red king crab recruitment will be ordered into a quantitative, computer oriented, conceptual model.

In addition a workshop on Tanner crab year-class strength formation will be planned and conducted in May 1995. This workshop will be similar to the red king crab workshop of 1994. It will involve the construction of a conceptual model with the objective of ordering all information on recruitment processes on Tanner crab into a model framework. This model will provide insight into research directions that will be most effective in developing an understanding of the sources of variation of year-class formation. Gaps in information will be identified. It is anticipated that the details available on Tanner crab recruitment biology will not be as extensive as for red king crab. The comparison between the two species will be valuable, and insight gained will help optimize further research at sea.

Benefits of Project

Results from this project will help plan future long-term research into areas of greatest consequence to crab stocks. In particular, we hope to attain a better understanding of the relative roles of fishing, predators, and environmental change on the dynamics of crab stocks. A cognizance of the magnitude of the effects of fishing and reduced spawning biomass on stock productivity will help us evaluate alternative crab management strategies within the context of natural variability. Likewise, understanding the strength of relationships between populations of crabs and their predators would help reveal the merits to potential future multispecies or ecosystem management approaches.

PROJECT 2: HANDLING MORTALITY OF RED KING CRABS

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Background and Need

Crab pots capture male and female red king crabs of a range of sizes. Yet, all Alaskan king crab fisheries are regulated by size and sex restrictions. As a result, females and small males are discarded. Mortality or sublethal effects may result from the catching, handling and discarding processes. Handling mortality occurs during fisheries when crabs are killed due to crushing, desiccation, exposure to extreme temperatures, and other factors. Sublethal effects of handling include a variety of injuries. Although crabs may survive amputation and regenerate lost limbs, these severely injured crabs may experience reduced growth.

Project Description

This project approaches the handling problem in two ways. The first approach, taken during FY 94, investigated the lethal and sublethal effects of handling by simulating the catching and discard processes in the laboratory. The second approach, proposed for FY 95, examines ways to minimize handling of red king crabs by the commercial fishery.

Little is known about red king crab behavior to fishing gear. Specifically, the proposed research will examine the behavior of red king crabs with respect to commercial crab pots, with the intent of formulating gear and/or deployment techniques which will decrease the catch of females and sublegal-sized males in the fishery. The reactions of king crabs to simulated commercial pots will be recorded and analyzed by means of video cameras and computer-assisted quantitative techniques. An improved fishing method, which

considers optimal soak time and modified crab pots, may facilitate the catch of legal male crab but limit the catch of female and sublegal male red king crabs. Such a method will be proposed and tested in a laboratory situation and *in situ*. These efforts may increase the catch efficiency of legal males with concomitant decreased catches of females and sublegal male king crabs.

Goals for FY 95

Milestones for the second year include:

(1) Document and quantify duration of aerial exposure, deck and water impact distance, and handling practices during commercial crab fisheries through first-hand observation.

(2) Completion of analyses and reporting of results of handling experiments conducted during the first year.

(3) Laboratory set-up and conduct of experiments on crab behavior to pot gear.

Mid-Year Progress

Progress to date are as follows:

(1) The data of red king crab handling experiments conducted during the FY 94 have been analyzed, and a manuscript of this study has been completed and accepted by a peer-reviewed journal for publication.

(2) A behavioral study of red king crab chemoreception to potential bait extracts has been completed. Five extracts of squid, mussel, herring, red king crab muscle, and red king crab ovary have been used to examine the sensory threshold and feeding threshold of red king crab.

(3) Observation of the commercial crab fishery has been conducted during the crab season by the principal investigator. Measurements of deck height and rail height, which are related to crab handling impacts, have been made from a variety of sizes of commercial crab vessels. Aerial exposure duration and handling practices have been documented. Body damage and mortality due to handling have been estimated. Based on the observation of commercial fishery, further studies concerning handling effects have been suggested.

(4) A laboratory has been set up for the study of the behavior of red king crab with respect to crab pots. This includes a round tank which is five meters in diameter, a dome-shaped tent housing this tank, an observation room of 8X8 feet, a tripod of four meters height for a video camera, and two sets of closed-circuit video systems.

One hundred and fifty red king crabs of a variety of sizes have been collected from the field for use in this behavioral study.

(5) Red king crab behavioral responses to a pot have been observed and recorded on video tapes. Also the escape behavior of red king crabs from a pot have been observed and documented.

Plans for Remainder of Year

Based on the observations of entering and escaping behavior of red king crabs to pots, a new type of pot will be designed. This pot is expected to facilitate the entry of crabs into the pot and the exiting of sublegal males and females while inhibiting the escape of legal males. The behavioral response of red king crabs to the new designed pot will be observed and recorded. An experiment with a group of crabs will be conducted by using a current commercial pot and the newly designed pot. The catch efficiency of the pots for legal males and liberation efficiency of sublegal males and females will be compared between the two types of pots.

The red king crab behavior with respect to pots, recorded on video tapes, will be analyzed by means of computer-assisted quantitative techniques. Video analysis software will be applied to this task.

Benefits of Project

This project relates to the long-term research plan in two ways. First, by providing experimental data on handling mortality on king crab stocks, this study will help us evaluate one proposed cause (handling) for crab stock declines. Second, by understanding crab behavior to pots, we may be better able to design gear regulations that minimize the number of crabs that are handled and discarded during fisheries, thereby reducing crab mortality.

PROJECT 3: CRAB GENETICS

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Background and Need

Fisheries cannot be managed successfully without understanding the underlying stock structure. Although we have made some progress (e.g., Seeb et al. 1990a,b) into genetic

stock identification of red king crabs (*Paralithodes camtschaticus*), several key questions remain about structure of BS/AI crab stocks. Some of the most important questions concern Tanner crabs and golden king crabs (*Lithodes aequispinus*). Answers to these questions will be useful to improve alignment of management units with genetic stocks.

Project Description

This project funds a Fishery Biologist II for 7 months, and associated laboratory supplies, to conduct studies into genetics of crab stocks. Specifically, this project will concentrate on an allozyme analysis of Tanner and snow crab stocks in Alaska. Tissues have been collected and most gels have been run. For FY 95 this project will focus on analysis and report writing. Following completion of this study, a small-scale pilot study of golden king crabs from Southeast Alaska, Bering Sea and Adak Island will be conducted to determine potential utility of allozymes for stock separation. A few red and blue king crabs (*Paralithodes platypus*) samples will be examined for comparison.

Goals for FY 95

Milestones for FY 95 include:

(1) Completion of analysis and manuscript for journal submission on Tanner and snow crab stock identification based on allozyme analyses.

(2) Completion of a pilot study on golden king crab allozymes: collection of samples, screening of gels, and draft report on findings. Results of allozyme analyses of a few blue king crab specimens will be compared to red and golden king crabs.

Mid-Year Progress

(1) Laboratory analysis of all Tanner and snow crab collections is complete. Analyses of these data are complete. Manuscript preparation is nearing completion.

(2) One collection of golden king crab (N=100) has been obtained from the Adak area fishery. Additional collections of golden king crab are being pursued from the Bering Sea (N=100) and from two sites in Southeast Alaska (N=200).

(3) Under existing state of Alaska funding sources, additional methods utilizing mitochondrial DNA (mtDNA) and DNA markers are currently being developed for use in stock identification studies of red king crabs, and Tanner and snow crabs in Alaska. These methods will also be useful in investigating questions relating to the hybridization of Tanner and snow crabs and gene introgression between these species in the Bering Sea. In addition, DNA methods developed for use in red king crabs may also be applied in the future to questions of golden king crab stock identification.

Plans for Remainder of Year

(1) An internal deadline of February 1, 1995 has been set for completion of the Tanner and snow crab stock identification draft manuscript ("Biochemical genetic variation of exploited Tanner crabs, *Chionoecetes bairdi*, and snow crabs *C. opilio*, in Alaska"). Following completion of internal review, this manuscript will be submitted to the Canadian Journal of Fisheries and Aquatic Sciences (CJFAS) for publication. A companion draft manuscript ("A genetic investigation of hybridization between *Chionoecetes bairdi* and *C. opilio*") will be submitted for review March 1, 1995, with subsequent submission for publication to CJFAS or another professional journal.

(2) Assuming additional collections of golden king crabs are successfully obtained from Southeast Alaska and the Bering Sea in the coming months, a pilot study of the utility of allozymes for stock separation will be conducted beginning in April 1995. A few blue and red king crabs will also be analyzed for comparison. Additional blue and red king crabs will be analyzed as time allows. Report preparation of findings of the pilot study are scheduled to begin May 1995.

Benefits of Project

This project addresses questions related to stock structure that were described in the long-term research plan (Kruse 1994c). Studies of crab genetics may provide bases for revision of fishery management units to better match underlying population structure. For example, it is not known whether Tanner crabs in Bristol Bay and near the Pribilof Islands should be managed as separate stocks. Further, appropriate management units for golden king crabs are uncertain. Last, results of this project may aid enforcement of crab regulations by helping to provide forensic data for court cases that involve fishing in areas closed to protect depressed crab stocks.

PROJECT 4: CRAB MANAGEMENT STRATEGIES

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Background and Need

Sound management requires precise estimates of population abundance and objective, quantitative evaluations of alternative management strategies. In Alaska, many crab stocks are assessed annually by trawl or pot surveys, some are assessed irregularly, and some stocks lack assessments. Population estimation models are needed to make the

best use of multiple years of data on crab size, sex, and carapace and reproductive condition. Such models are necessary to evaluate measurement errors in annual surveys and to generate abundance estimates for stocks that are infrequently assessed.

Estimates of biological production parameters are needed to determine optimal management strategies and to calculate fishery yields for the king and Tanner crab stocks off the coast of Alaska. For most stocks, the common biological and reference points, such as $F_{0.1}$, yield per recruit, optimum yield, and stock-recruit relationships have not been computed. The utility of fishery thresholds and alternative harvest rates have not been thoroughly evaluated either.

Project Description

This project funds a Biometrician I to conduct quantitative analyses of abundance, biological, and fisheries data for crab stocks. Analyses focus on information germane to harvest policy: population estimation, optimal thresholds, biological reference points, natural and handling mortality, size limits, stock and recruitment relationships, effects of fishing on growth and reproductive success, sustainable yields, and molting seasonality as related to fishing seasons. Top priority was placed on development of length-based population estimation models that integrate multiple years of survey assessment and catch data, analyses of stock-recruit relationships, and evaluation of the utility of thresholds and harvest rates to optimize the trade offs between high yield and low variability in yield.

Goals for FY 95

The second year work was designed to advance new projects and to finalize studies begun in the first year. For Bristol Bay red king crab, work in FY 95 focuses on:

(1) A paper on the length-based population estimation model, drafted during the first year, will be published.

(2) A modeling study of harvest strategies based on threshold and exploitation rate, initiated in the first year, will be completed. This includes final simulations and manuscript preparation.

(3) The sensitivity of the harvest strategies model will be analyzed through computer simulations.

(4) Stock rebuilding strategies will be analyzed.

Work on other king and Tanner crabs will address:

(5) Development of a catch-length analysis for crabs without survey information.

(6) Completion of a length-based population model for Bering Sea Tanner crab. This includes final manuscript preparation.

(7) Initiation of work on a population model for another red king crab stock such as Norton Sound or Adak Island. These two stocks provide excellent historic contrast: the Adak fishery which, though small now, was large at one time, and the Norton Sound red king crab stock which remains quite healthy.

Mid-Year Progress

A manuscript (Zheng et al. 1995) for the length-based population estimation model for Bristol Bay red king crabs was finalized and accepted by CJFAS for publication. The modeling study on optimal harvest strategies for Bristol Bay red king crab was completed, and a manuscript (Zheng et al. MSa) was submitted to CJFAS for publication.

A catch-length analysis for crabs without survey information and a length-based population model for Bering Sea Tanner crab were completed and two draft manuscripts (Zheng et al. MSb,c) have been prepared. The former has been submitted to Fishery Bulletin, and the latter is currently being reviewed within ADF&G.

Plans for Remainder of Year

Manuscripts on optimal harvest strategies for Bristol Bay red king crab, the catch-length analysis for crabs without survey information, and the length-based model for Bering Sea Tanner crab will be revised once we receive comments from reviewers. Stock rebuilding strategies for Bristol Bay red king crab will be analyzed, a sensitivity study will be conducted, and a manuscript describing the results will be prepared. Work on a population model for another red king crab stock such as Norton Sound or Adak Island will be initiated.

Benefits of Project

This project relates to the long-term research plan in two ways. First, for all major crab stocks ADF&G intends to develop population estimation models -- models that provide estimates of crab abundance that are relatively insensitive to survey measurement errors in any single year. Second, because these models embody critical biological parameters specific to a species and stock, they provide a framework within which to evaluate optimal harvest strategies.

UPDATE ON PROJECTS FUNDED DURING FY 94

Two crab research projects were funded and completed under Cooperative Agreement NA37FL0333 during the first year (FY 94), July 1, 1993 to June 30, 1994. In one of

these, Tanner crab reproduction was studied by Dr. A.J. Paul of the Institute of Marine Sciences, UAF. As reported in the annual report for last year (Kruse 1994b), all work on this project was completed and a manuscript of the results was submitted to the Journal of Crustacean Biology. Since we reported on this project, the manuscript has been accepted and will soon be published by this journal. The citation for this paper is Paul et al. (1995).

A second project funded during the first year of cooperative agreement was the purchase of a 26' aluminum skiff, *R/V Instar*, to conduct near-shore crab research studies. Whereas federal funds paid for the one-time purchase of the vessel, state of Alaska general funds pay for annual operational costs. During July 1 though December 31, 1994, the *Instar* was used to conduct two research studies.

In the first study, ADF&G biologists monitored young-of-the-year (YOY) red king crabs collected by artificial collectors in Chiniak Bay, Kodiak Island, in an ongoing attempt to relate the number of settling crabs to subsequent recruitment to the fishery. In late September to mid-November, 69 stations were sampled. Several hundred collectors from 42 stations were retrieved with the use of the skiff's hydraulic system. Artificial collectors were processed, and several hundred YOY red king crabs were collected and measured. In November the *Instar* was used to make two SCUBA dives at two stations with artificial collectors in Chiniak Bay. The collectors from one of these stations were retrieved.

In the second project, the *Instar* was used to retrieve and deploy a thermograph to maintain a 25-year record of hourly bottom temperatures at 35' below mean lower low water (MLLW) in Trident Basin, Kodiak Island. In November, the *Instar* was used for a scuba dive to retrieve the thermograph that had recorded temperatures for nearly nine months. A second thermograph was deployed to record the temperatures over the next nine months. These data will be incorporated into an ADF&G report now being prepared on the 25-year bottom temperature record at this site.

During the remainder of this year, January 1 through July 30, 1995, the *Instar* will be used to deploy artificial collectors at 55 indexing stations in late March and early April, and it will continue to provide a dive platform for nearshore research.

ACKNOWLEDGMENTS

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